THE HOMOLOGIES OF THE OCCIPITAL AND FIRST SPINAL NERVES OF AMIA AND TELEOSTS.

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IN a recent and extensive work Fürbringer (No. 2) treats of those nerves of vertebrates that lie between the vagus, or vago accessorius, and the first free spinal nerve. This last nerve, although not definitely so defined by him, is seen, by inference, to be the first nerve posterior to the last one that issues from the cranio-spinal canal either through a foramen in the cranium or by an aperture that lies anterior to a dorsal vertebral arch segmentally related to the cranium. The nerves that lie between this first free spinal one, so defined, and the vagus are all included under the general term spino-occipital, and are subdivided into two groups. The nerves that are assigned to one of these two groups are said to have belonged, with their associated skeletal elements, since an early phylogenetic period, to the occipital region of the skull, and they are accordingly called the occipital nerves. Those belonging to the other group are said to have acquired their relations to the cranium by a more recent assimilation of their associated skeletal elements, and to be as yet but incompletely emancipated from the spinal nerves. As they thus represent an intermediate stage between the nerves of the first group and the free spinal ones they are called the spino-occipital nerves. These three names for the nerves here under consideration will be adhered to in the present article, although I think the adoption of them in the present state of our knowledge of the subject a needless complication, and even a possible source of error or inconvenience.

From Fürbringer's several special descriptions of these two groups of nerves, and his several general statements regarding them and their associated skeletal elements, it is seen that he considers as occipital nerves all those that issue from the

cranium in that part of it that lies between the posterior limit of the protometameric cranium of Sagemehl's descriptions (No. 6, p. 526) and the posterior limit of the paleocranium; and that he considers as spino-occipital nerves all those that issue in that part of the auximetameric skull of Sagemehl's descriptions that lies posterior to its protometameric portion.

These definitions of these nerves seem at first sight to be morphologically concise and definite. A little consideration will, however, show that two suppositions can be made regarding the segmental position of the nerves thus incorporated in the skull. They can either lie, morphologically, between the dorsal arches of two adjacent assimilated vertebrae, and so become enclosed between those vertebrae as they fuse with each other and with the skull; or they can lie, morphologically, posterior to the dorsal arches of the assimilated vertebrae, become first incorporated in those vertebrae and then with them in the skull. Under the first supposition the last nerve incorporated in the skull would lie anterior to the dorsal arch of the last incorporated vertebra, and anterior to the intermuscular septum related to that vertebra. Under the second supposition it would lie posterior to the same arch and septum. Each nerve of the series would accordingly belong, under the first supposition, to a trunk muscle-segment one anterior to the one it would belong to under the second supposition. From Fürbringer's descriptions it is not evident, in each particular case, to which of these two categories the nerves under consideration belong. That, in ganoids and teleosts at least, he considers them as belonging definitely to the first category is evident from his statement regarding Polyodon. Of this fish he says (No. 2, p. 449): "Für mich bildete das Verhalten an dem untersuchten Exemplare von Polyodon, wo die erste dorsale Wurzel (a) eine durch ein partielles Ligament markirte Stelle des Schädels passirt, das entscheidende Kriterium. In dieser Stelle erblickte ich die noch nicht vollkommen verwischte Grenze zwischen dem selachierartigen (protometameren) Cranium und der Wirbelsäule, und in der dorsalen Wurzel diejenige des ursprünglichen ersten Spinalnerven, der nun zum ersten occipito-spinalen Nerven (a) geworden ist."

It is thus evident, in so far at least as the ganoids and teleosts are concerned, that the most anterior spino-occipital nerve of Fürbringer's nomenclature must lie, morphologically, between the protometameric part of the cranium and the first posterior assimilated, or partly assimilated, vertebra. The most posterior spino-occipital nerve, where there are more than one, should then lie, necessarily, between the last and the next to the last assimilated vertebrae, and the first free spinal nerve between the last assimilated vertebra and the first free one. These necessary relations of the last-named nerves to the skull and vertebrae, thus definitely indicated by inference, seem not to have been carefully borne in mind by Fürbringer in his general definitions and conclusions, although it is sufficiently evident that they are of primary importance in any attempt at comparison.

In Amia calva, Fürbringer found, as I had found independently of him (No. 1), four nerves between the vagus and the first free spinal nerve. The most anterior of these four nerves is said by him to belong to the occipital nerves of his nomenclature, the other three to the spino-occipital ones. The occipital nerve is designated by the letter *z*, the other three by the letters *a*, *b*, and *c*. The nerve next posterior to the nerve *c* is said to be the first free spinal one, and is designated by the number 4. In other fishes, in which there may be other occipital or spino-occipital nerves, not found in Amia, the additional occipital ones are said to always lie anterior to the one occipital nerve of Amia, and the additional spino-occipital ones always posterior to the three spino-occipital ones of that fish.

In teleosts, Fürbringer finds but two spino-occipital nerves, and he considers them as the homologues of the nerves *b* and *c* of Amia. On page 465 of his memoir he says, that the occipital nerves are wholly wanting in all teleosts, and that the existence of the first spino-occipital one has not yet been established in any teleost known to him. On page 543 he further says, that in teleosts, not only all the occipital nerves but also the first spino-occipital nerve is "vollständig rückgebildet." The nerve next following the nerve *c* is said to always be, as in Amia, a free spinal one, and it is accordingly designated, as in that fish, by the number 4.

In my work on Amia, already referred to, I fully described all the occipital and first free spinal nerves in that fish, giving at the same time their relations to the anterior muscle-segments of the trunk, and the relations of these segments and their myosepta to the bones of the skull, to the anterior vertebrae, and to the bones of the shoulder girdle. Similar descriptions of these nerves, and of the segments and bones they are related to, form part of a work I have now nearly finished on Scomber scomber. The dissections of this fish have been made under my direction, in my laboratory here at Menton, by Dr. J. Dewitz, and can be briefly summarized as follows :

The sixth intermuscular septum is the first one that extends from the mid-dorsal to the mid-ventral line of the body. The ventral parts of the fifth and fourth septa, as seen on the inner surface of the body wall, run downward, from the vertebral column, on to the dorsal edge of a large accessory shoulder-girdle bone, and there end. On the outer surface of the body the fifth septum runs downward and forward to the hind edge of the clavicle, at about the middle of its length, and there ends. The fourth and more anterior septa run downward to and end at the dorsal edge of the same bone. The sixth muscle-segment, the one that lies immediately in front of the sixth septum, is thus the first one that extends ventrally the full length of the clavicle, and the fifth septum is the one that marks the apparent septal position of the ventral end of the clavicle. The fifth septum of Scomber is thus, in its relation to the clavicle, the apparent homologue of the same septum in Amia.

Centrally the fifth septum is attached to the second free vertebra of the fish, the fourth septum being attached to the first vertebra. Articulating with each of these two vertebrae there is, on each side, a single rib, which lies in the intermuscular septum attached to the vertebra, at the line where that septum is intersected by the horizontal muscle-septum. On the third and next following vertebrae there are, in addition to these horizontal ribs, ventral ones, which lie along the inner surface of the trunk muscles, in the mesial edges of the septa of the vertebra to which they are related. In one specimen a short rudimentary ventral rib was found on the second vertebra also.

The second and third intermuscular septa have their central attachments on the occipital part of the skull, the large occipito-superclavicular ligament lying in the third septum, with its outer end in the horizontal line of the outer ends of the horizontal ribs.

The line of attachment of the first septum traverses the hind end of the posterior process of the intercalar, and the pedicle and three other processes of the suprascapular are enveloped in, or lie in definite relations to, different parts of it.

The anterior muscle-segments, on each side of the head, extend forward on the dorsal surface of the skull in two deep grooves, the lateral one of which corresponds closely in position to the temporal groove of Amia. This groove lies, however, in Scomber, on the dorsal surface of the parietal and frontal bones instead of, as in Amia, between those bones and the chondrocranium. The anterior margin of the muscle-segments in Scomber extends forward slightly beyond the posterior portion of the supraorbital lateral canal, covering externally that canal, while in Amia it only reaches, approximately, the hind edge of the frontal bone. The temporal extensions of the trunk muscles, which are certainly secondary adaptations, thus extend considerably farther forward in Scomber than they do in Amia.

In Amia the first intermuscular septum has the same general relations to the intercalar and to the pedicle of the suprascapular that the first septum in Scomber has. The fourth and fifth septa have their central attachments to the two occipital arches, and each usually contains one of the two occipito-supraclavicular ligaments of the fish. In one larval fish these two ligaments were found in the third and fourth septa.

In Scomber the dorsal and ventral roots of the nerves of the fifth and sixth trunk-segments both traverse foramina that perforate, respectively, the first and second free vertebrae of the fish, the foramina in each vertebra lying posterior to the intermuscular septum that has its attachment to the vertebra. Both nerves have dorsal, ventral, and horizontal branches, and from each nerve a communicating branch is sent dorsally, but

morphologically forward to the dorsal branch of the next anterior nerve.

The ventral branch of the nerve of the fifth segment sends a large branch forward to join a nerve formed by the fusion of the nerves of the three next anterior segments. From the large nervous trunk, so formed, a branch is sent downward and forward to the sternohyoideus muscle, the remainder of the trunk, as the nervus pterygialis, continuing downward and backward to the pectoral fin. After giving off this anterior branch, the main nerve continues downward and enters the ventral fin, no other branch being sent from it to the pectoral fin.

The ventral branch of the nerve of the sixth segment sends an important branch forward to join the nerve of the fifth segment, the branch joining the latter nerve distal to the point where the anterior branch of that nerve is sent forward to join the three next anterior nerves. As this branch thus forms part of a plexus which is evidently the so-called brachial plexus of the fish, it is highly probable that the nerve of the sixth segment takes part in the innervation of the pectoral fin. After giving off this branch the main nerve continues downward and enters the ventral fin.

The nerve of the seventh segment has no perceptible connection with the anterior nerves. It thus, in all probability, takes no part in the formation of the brachial plexus, and consequently no part in the innervation of the pectoral fin.

Anterior to the nerve of the fifth muscle-segment, between it and the vagus, there are in Scomber but three nerves. The two posterior ones are represented by both dorsal and ventral roots ; the anterior one by a ventral root only. All of these roots traverse foramina in the occipitale laterale, the foramina lying close together and varying in number from two to five. The one or two foramina of the posterior nerve were always found separate and distinct from those of the two anterior ones, and they lay posterior to, and close to, the third intermuscular septum. Whether the foramina of the two anterior nerves also lay posterior to this septum, or were traversed by it, or lay anterior to it, was not noted. The five roots issue close

together, and the common ganglionic mass formed on them lay always posterior to the septum.

From this ganglion three dorsal, three ventral, and two horizontal branches arise, but as the anterior one of the two latter branches soon separates into two nearly equal parts, there are thus three horizontal branches, in all, associated with the ganglion. The three dorsal and three horizontal branches are distributed to the fourth, third, and second muscle-segments, in a manner similar to that of the corresponding branches in the posterior segments. The three ventral branches unite to form a single nerve which, after being joined by a branch of the nerve of the fifth segment, is distributed, as above stated, to the sternohyoideus muscle and to the muscles of the pectoral fin. As the branches of these three segmental nerves all arise from a single ganglion, there were naturally no anterior communicating branches associated with them.

There was no indication whatever of a separate nerve related to the first muscle-segment, and no branches of the nerve of the second segment could be traced forward into it.

In Amia, the four spino-occipital nerves belong to the second, third, fourth, and fifth muscle-segments, there being in Amia, as in Scomber, no separate nerve related to the first segment. The nerves of the second and third segments issue from the cranium through foramina in the occipitale laterale, the next two issuing through apertures in the membranes that fill the spaces between the cranium and the occipital arches. The first two nerves are represented by ventral roots only, the other two by both dorsal and ventral roots. All four of the nerves take part, as do the nerves of the corresponding segments in Scomber, in the innervation of the sternohyoideus muscle, and a part of the fourth nerve joins the nerve of the sixth muscle-segment to form the nervus pterygialis. Posterior to the nerve of the sixth segment several other nerves enter, independently, the pectoral fin.

We thus see that the first six muscle-segments of the trunk of Scomber closely agree, in their relations to the dermal bones of the cranium and shoulder girdle, with the corresponding

segments of Amia; and that the nerves related to these segments in the two fishes, that is, the first five postvagal nerves, agree even more closely with each other in their general peripheral distribution. The relations of these several nerves and segments to the skull and vertebrae are, on the contrary, totally different in the two fishes; for the fourth and fifth intermuscular septa have their respective attachments, in Scomber, to the first and second free vertebrae, while in Amia they have their attachments to the two occipital arches. This marked difference in the two fishes would find an evident and simple explanation in the assumption that the first two free vertebrae of Scomber were, in Amia, partly incorporated in the occipital part of the skull. But this assumption is directly opposed to Fürbringer's general conclusions, according to which it must be assumed that the first two free vertebrae in the two fishes are strictly homologous. Under the first assumption there would be, in the two fishes, a marked accord in the nerves and muscle-segments of the region. Under the second assumption there are marked differences to be explained and accounted for.

In Scomber, for instance, the fourth muscle-segment lies between the hind end of the skull and the first free vertebra, and it is innervated by the posterior one of the three nerves that issue through the foramina in the occipitale laterale. The next, or fifth, muscle-segment lies between the first and second vertebrae, and is innervated by the first free spinal nerve, the roots of that nerve traversing foramina that lie in the first vertebra close to, but posterior to, the intermuscular septum that has its attachment to that vertebra. In Amia the first free spinal nerve innervates the muscle-segment that lies between the hind end of the skull and the first free vertebra. The homologue, in Scomber, of the first free spinal nerve of Amia is, accordingly, in so far as the morphological relations of the nerves to the skull and vertebrae are concerned, the last spino-occipital nerve, and not the first free spinal one. The insufficiency of Fürbringer's definitions is thus at once evident, for an examination of the skull alone in the two fishes would not in any way indicate that the last spino-occipital nerve was not, in each, similarly related to the last occipital vertebra.

But even if this difference in the morphological relations of the nerves to the vertebrae were evident in the skull alone, Scomber would still present a marked exception to Fürbringer's general formula; for, if the most anterior spino-occipital nerve of this fish is considered as nerve *b* of his nomenclature, the most posterior one would necessarily be nerve *d*, and not nerve 4; and such a nerve is not given, or its existence intimated, in any of the teleosts considered by him. If, on the contrary, the most posterior nerve is to be considered as nerve *c*, the most anterior one would be nerve *a*; a nerve said by him to be absolutely wanting in all teleosts.

The successive incorporation of vertebrae in the occipital part of the skull is attributed by Fürbringer, primarily (unmittelbar), to the reduction and disappearance of the myomeres that give to the vertebrae in question their movements relative to each other and to the skull (No. 2, p. 548). This same reduction and subsequent disappearance of the anterior muscle-segments is also said to precede and be the primary cause of the reduction and disappearance of the nerves related to them (No. 2, p. 543).

Why, then, is there, in the adult of both Scomber and Amia, an anterior muscle-segment, relatively well developed, without any indication whatever of a separate spinal-like nerve related to it? And why is it that in Amia the last so-called occipital vertebra is incorporated in the skull after the fish has passed the age represented by a 50 mm. specimen, and yet, between the age represented by a 12 mm. larva and the adult fish, there is no related reduction in the number of myotomes? As there are, both in the adult and in larva, four muscle-segments anterior to the one that, in the adult, lies between the last assimilated vertebra and the next anterior one, some reduction in this number might have naturally been expected. In Acipenser ruthenus, according to Sewertzoff (No. 7, p. 232), there are always, in the adult, two or three spino-occipital nerves anterior to the one that innervates the most anterior myotome.

The temporal extensions of the trunk muscles certainly represent to some extent, in Scomber and in Amia, independent invasions of the cranial region, for in Amia these muscles lie

internal to the parietal bone, while in Scomber they lie external both to that bone and to the frontal. This seems to indicate that Amia and Scomber represent separate lines of descent from some fish in which the trunk muscles had not as yet invaded the temporal part of the skull to the extent they have in these two fishes. In Scomber, the muscles extend farther forward than they do in Amia. If, then, there are in Scomber two less anterior myomeres than there are in Amia, and the anterior segments in both fishes are in process of reduction, what is the explanation of this independent and apparently aggressive activity in the muscles?

Furthermore, aside from the fact that the last spino-occipital nerve perforates the occipitale laterale, I find no indication whatever, in the skull of Scomber, of the incorporation in it of either of the two occipital vertebrae of Amia; and the simple fact that this nerve is incorporated in the occipital part of the skull is not necessarily any indication whatever, in any fish, of its being a spino-occipital rather than a post-occipital one.

My work thus leads me to conclude, not only that the spino-occipital and first free spinal nerves in Scomber and Amia are homologous structures, but also that the first two free vertebrae of Scomber are represented in Amia by the two incompletely incorporated occipital vertebrae. In this my conclusions are directly opposed to those arrived at by both Sagemehl and Fürbringer in their comparisons of Amia with other teleosts.

Sewertzoff (No. 7, p. 240), in his examination of the skull of Amia, simply confirms Sagemehl's earlier observations; that is, he finds three spino-occipital nerves instead of four. In Lepidosteus osseus, he says (No. 7, p. 238) that Balfour and Parker's investigations show that the myotomes in embryos of that fish extend forward to the ear capsule, exactly as his own investigations show that they do in embryos of Acipenser ruthenus. In the adult Lepidosteus, he finds on each side of the head, in addition to the two foramina said to have been previously described by Gegenbaur, a third and more posterior one which "durch eine enge Ritze, wie durch einen Riss mit dem hinteren Rande des Bogens verbunden ist" (No. 7, p. 239). The anterior of these three foramina perforates the occipitale

laterale, the other two the "angewachsenen" occipital arch of the fish. The posterior foramen is said to resemble exactly the foramina found in the dorsal arches of the free vertebrae, and Sewertzoff hence concludes that it unquestionably gives passage to a spinal-like nerve. This nerve is said by him to "belong" to the so-called occipital arch of the fish and to indicate, with the next anterior nerve, that that arch is formed by the fusion of two dorsal vertebral arches instead of representing but one such arch, as Gegenbaur asserts. The drawing which accompanies Sewertzoff's descriptions seems to me to show, beyond question, that the nerve here under consideration, and the following spinal ones, each innervate the muscle-segment that lies immediately posterior to the arch the nerve in question perforates. The last nerve that perforates the skull is, accordingly, a post-occipital and not a spino-occipital one, exactly as in Scomber; and as it seems, both from Sewertzoff's figure and descriptions, to have been but recently, and still incompletely, incorporated in the skull, this may account for its apparent absence in the specimen described by Gegenbaur. This nerve in Lepidosteus is considered by Sewertzoff as the homologue of the last spino-occipital nerve in Amia, and the two vertebral arches said to be represented in the single occipital arch of Lepidosteus are accordingly considered as the homologues of the two partly assimilated occipital arches of Amia. If the posterior spino-occipital nerve of Lepidosteus is, as it seems to be, a post-occipital nerve, this comparison is evidently not correct.

With Acipenser, so fully described by Sewertzoff, I am unable to make any comparison, the embryos of Amia that I have as yet investigated not having been sufficiently young to show whether or not a certain number of the anterior postotic somites disappear in this fish without giving origin to permanent muscle-segments. It seems to me, moreover, that there is some confusion in Sewertzoff's descriptions. On pages 224–8 of his memoir he says, that in stage *B* of Acipenser the first myotome posterior to the ear capsule still exists, but is relatively much reduced in size. The first dorsal root in the specimen representing this stage lay opposite the fifth myotome on the

right side of the head, but opposite the sixth myotome on the left side. The first ventral root lay opposite the fourth myotome on both sides of the head. In stage B_2 the first myotome is said to still exist, and the nerves to have the same relations to the myotomes as in stage *B*. In stage *C* the reduction of the anterior myotomes is said to have advanced no further than in the preceding stages. The first two myotomes in this stage are then said to have no related nerves, the third and fourth to have ventral roots related to them, and the fifth to have a complete spinal nerve. Later he says of this same stage, "verschwunden sind das vordere Myotom (M_1) des Stadiums B_2 und die vordere ventrale Wurzel ($sp.d_1$)" and "jetzt ist das vordere Paar der dorsalen Wurzeln, (welches gegenüber den Myotomen des 6ten Paares, $sp.d_2$, Fig. 1, *lag*), von beiden Seiten gleich entwickelt." That he has here in some way changed the numbering of the myotome seems evident, but it is, nevertheless, not at all certain, for although he says in one place that the number of myotomes has changed, he says in another that it has not changed. Whether this uncertainty in the numbering is perpetuated or not in the descriptions of later stages is difficult to judge. So far as the adult is concerned, the definite statement on page 232, that there are no myotomes anterior to the post-occipital one, shows a condition totally different from that found in Amia. The post-occipital myotome is said to be innervated, as it is in Amia, by the first free spinal nerve.

In the Characinidae, Sagemehl (No. 5, p. 58) found but one spino-occipital nerve, and he considered it as the homologue of the middle one of the three spino-occipital nerves found by him in Amia; that is, as the homologue of nerve *b* of Fürbringer's nomenclature. The first nerve posterior to this nerve is said to lie posterior to the stapes, and to innervate the muscle-segment that lies between the first and second vertebrae. The stapes is said to represent the dorsal arch of the first vertebrae, and the claustrum to be the homologue of the posterior occipital arch of Amia. As the nerve *b* in Amia lies anterior to the anterior occipital arch of that fish, there are thus, according to Sagemehl, two nerves missing in the Characinidae, one of which would be the homologue of the nerve *c* of Amia,

and the other the homologue of the post-occipital or first free spinal nerve. The latter nerve, although wanting in the Characinidae, is said to be found in Silurus glanis, and to lie in that fish between the claustrum and stapes.

There are thus, according to Sagemehl's descriptions, exactly the same number of spinal, or spinal-like, nerves indicated in the occipital part of the skull of the Characinidae as are found in Scomber, and they have exactly the same relations to the vertebral components of the skull. The same is true, according to his descriptions (No. 5, pp. 527, 543), of many other teleosts, among which may be mentioned Esox, Umbra, Perca, the Gadidae, Cyprinodontidae, and Cyprinidae. In the Cyprinidae the nerve *c* is said to be wanting, as it is in the Characinidae. In the other fishes named, excepting Esox, it is said to be found. Whether it is or is not found in Esox is not stated. Fürbringer, however, gives it in this fish (No. 2, p. 466). In the Characinidae, Fürbringer gives nerve 4, differing in this from Sagemehl. He agrees with the latter author as to the absence in these fishes of nerve *c*. My work would incline me to think that the nerve considered by both these authors as nerve *b* was in reality nerve *c*, and that nerve *b* had been missed by both of them in dissection.

In Carassius, Sewertzoff says (No. 8, p. 423) there are three dorsal vertebral arches in the occipital part of the skull. In Amia I found (No. 1, p. 727) that the same number of arches were indicated in the region occupied by the cartilaginous occipitale laterale, and that this number of vertebral arches corresponded to the number of muscle-segments. The muscle-segments in Scomber indicate a similar number of vertebral arches in the occipital part of the skull of that fish, Scomber thus agreeing in this with Carassius.

In Salmo salar, Harrison (No. 3) gives two persistent occipital muscle-segments, and says that a third and more anterior segment, found in embryos twenty-four days old, disappears entirely after that age. The first persistent segment is said to have no spino-occipital nerve related to it. The second segment is said to be related to the hypoglossus, which nerve in young stages is found "von demselben Bau als die übrigen" spinal

nerves, but in older ones is usually represented by a ventral root only. The third segment lies between the hind end of the skull and the first free vertebra, and the nerve related to it is said to be the first spinal nerve. This nerve, however, leaves the vertebral canal with the hypoglossus, "durch eine einzige Oeffnung zwischen dem Occipitale und dem ersten Wirbel." What this opening may be in or through is not indicated, but the fact that the hypoglossus traverses it warrants the supposition that, in the adult, it must be enclosed in the hind end of the skull. The post-occipital nerve of Salmo thus probably agrees, in this respect, with the corresponding nerve in Scomber. Young larvae of Salmo also agree with Scomber in the number of occipital muscle-segments, but there is, in Salmo, one less spino-occipital nerve than in Scomber.

In Necturus, Platt (No. 4) says that the first postotic somite aborts and disappears without giving rise to muscle fibers, and that this is true also for all other vertebrates above the Selachii of which she knows. If it be assumed that Amia agrees in this with Necturus, the nerve of the fifth muscle-segment is seen to be, in both these animals, the anterior nerve of the brachial plexus. The dorsal arch next posterior to this nerve is, in Amia, the posterior occipital arch. In Necturus it is the arch of the third free vertebra. The skull of Amia would thus, under this assumption, contain three vertebrae found free in Necturus. If, on the contrary, it be assumed that the first postotic somite of Amia does not disappear, but gives origin to muscle fibers, the two occipital arches of Amia would correspond to the dorsal arches of the first two free vertebrae of Necturus, as they do to the dorsal arches of the same vertebrae in Scomber. The occipital arch of Necturus would then represent the entire cartilaginous occipitale laterale of Amia, if that structure represents but a single vertebral element, or the posterior one of the three vertebral elements that enter into it, if there are three. Which of these two suppositions, if either, is the correct one can only be known after the investigation of larval stages of Amia earlier than any I have as yet examined.

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